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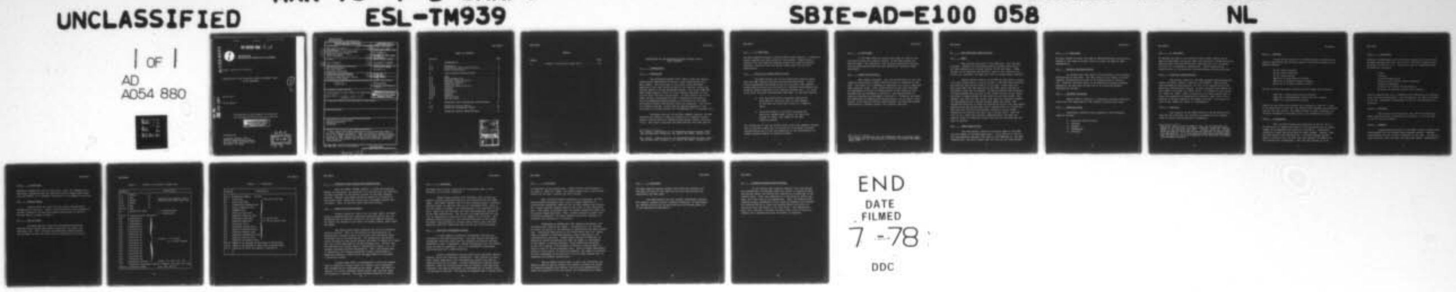

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DESCRIPTION OF THE MILSATCOM LOADING PROGRAM 'OPAL': GPSCS ADDENDUM

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March 1978

Final Report

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This report describes modifications that have been made to the OPAL computer program in order to perform loading calculations for GPSCS satellites. The modifications include masking routines to make temporary changes to the URDB and a procedure that allows the program user to generate different satellite configurations.

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1. INTRODUCTION.

1.1 Background.

The MILSATCOM Systems Office (MSO) within the Defense Communication Agency(DCA) maintains a User Requirements Data Base (URDB). This data base is the single source document approved by the Joint Chiefs of Staff, for planning, sizing and systems design of future MILSATCOM systems. Use of the URDB has been largely manual, which is a very tedious procedure in view of more than 2000 line item entries. To make greater use of the URDB, the MSO contracted with ESL Incorporated to develop a flexible MILSATCOM loading program to interface with the URDB and perform loading calculations using DCA computers. The resulting computer program, termed OPAL for optimum allocation, was delivered to the MSO together with documentation[1,2] in October 1977.

Following delivery of the OPAL computer program, the MSO modified the contract to add the capability of handling various General Purpose Satellite Communications System (GPSCS) configurations. This report describes the modifications that were made to

[1] P.D. Shaft, "Description of the MILSATCOM Loading Program 'OPAL'" ESL Incorporated, Sunnyvale, CA, Report ESL-TM888, October 1977.

[2] G.D. Heinz, "Users Guide for the MILSATCOM Loading Program 'OPAL'" ESL Incorporated, Sunnyvale, CA, Report ESL-TM887, October 1977.

1.1 -- Continued.

the OPAL computer program to handle GPSCS configurations. A companion report modifies the users guide for the program. These reports, together with the modified computer program and modified program listings, constitute the deliverable items under the contract modification.

1.2 Overview to GPSCS Modifications.

The GPSCS project was in the preliminary planning phase when the OPAL computer program modifications were begun. Since a firmly established configuration was not available, the computer program modifications took the form of a flexible configuration that could be readily modified by the computer program user. To accomplish this, two major modifications were made to the OPAL program:

1) Data base modification (masking) subroutines were added to allow the user to make changes in the URDB and other data files on a temporary basis.

2) Additional models of satellite antennas and satellite transpoinders, typical of those suggested for GPSCS, were added to the OPAL computer program.

The combination of the two modifications allows the computer program user to generate models for a wide-variety of possible satellite configurations and to test the capability of the configuration to handle selected subsets of required traffic.

1.2 -- Continued.

If the OPAL computer program user does not need to use the modifications,the original version of the OPAL program can still be used. All features of the original program are retained without modifications when the user specifies a satellite other than GPSCS.

1.3 Report Organization.

This report describes only the modifications to the OPAL computer program when a GPSCS satellite model is specified by the user. The report is an addendum to Reference [1], and is organized along parallel lines. Thus, modifications to the file structure are discussed in Section 2, modifications to the satellite link calcualtions are discussed in Section 3, and modifications to satellite loading are discussed in Section 4. Similarly, we retain the philosophy of keeping descriptive material in one report (this report) to be read for general understanding, and detailed program instructions in another report[3] for frequent reference.

[3] G.D. Heinz, "Users Guide for the MILSATCOM Loading Program 'OPAL': GPSCS Addendum: ESL Incorporated, Sunnyvale, CA, Report ESL-TM938, March 1978.

2. FILE STRUCTURE MODIFICATIONS.

2.1 URDB.

The original structure of the URDB data file has been retained. However, we have added masking routines which allow the OPAL program user to enter changes in the data base. These changes are a temporary modification, used in the execution of a single run, whereupon the URDB data file is automatically restored.

Changes may be entered in the URDB by specifying a single line item (using Fields A and B jointly). The user then specifies the field(s) and the new value(s) to be used. Since there are more than 2000 line-item entries in the URDB, making changes on individual items can be tedious. To help alleviate this situation, the OPAL program user can call up all common entries in any field and enter a common change in that field or any other field. For example, the user can call up all line items in a specific network (by specifying Field D and the network name) and change the designated satellite to GPSCS (by specifying Field P and then GPSCS). Masking calls may specify more than a single entry in a field and more than one field if simultaneous conditions are to be met. Changes may be entered into more than a single field. When the call is to a field that contains numerical data, the user can specify ranges of numerical values that must be satisfied for the mask to operate.

2.2 URDB Augmentation.

The same masking subroutine that was added to the URDB was also added to the URDB Augmentation. Since there is a one-to-one correspondence between line items in the URDB and in the URDB Augmentation, the OPAL program user can call up line item entries

2.2 -- Continued.

by using fields in either the URDB or URDB Augmentation and entering changes in the same or another field in either the URDB or URDB Augmentation.

2.3 Terminal Characteristics.

No changes have been made to the structure of the terminal characteristics data base. The OPAL program user wishing to modify terminal characteristics cannot do so interactively or during a run. Terminal characteristics can be modified by making permanent changes in the data base through use of an ancillary program developed by the MSO.

2.4 Terminal Locations.

Remarks made in Section 2.3 concerning terminal characteristics are also applicable to the terminal locations data base.

2.5 Satellite Data.

Previously, satellite data appeared in five different types of records:

a. Satellite identification
b. Location
c. Antenna
d. Transponder
e. Priority.

2.5 -- Continued.

No changes are made in the satellite data records (which can be used as previously) unless the OPAL user specifies a GPSCS satellite. When the user specifies GPSCS, major modifications are introduced as described in subsequent subsections. These changes allow modifications to the Satellite Data Base through the setup program.

2.5.1 Satellite Identification.

The earlier version of the OPAL program contained specific models for AFSAT, DSCS-II, DSCS-III, and FLTSAT.* These models were accessed by specifying AF, D2, D3, or FL respectively in the satellite identification record. We have retained these models and have added a new model for GPSCS, which is accessed by specifying GP. When the GPSCS model is specified, the OPAL program user is given the capability of generating a satellite model with a wide variety of options regarding the number and types of antennas as well as the number and types of transponders.

2.5.2 Location.

The location of the GPSCS satellite can be specified by entering the longitude; the latitude is assumed to be 0 degrees since we retain the geostationary assumption.

*Additional models, such as NATO-IV (N4), can be generated and placed in the Satellite Data Base as desired, using the original format of the Satellite Data Base. Traffic can be run through this new model by using the new masking routines to change satellite designation. It is only when the OPAL user specifies GPSCS, that the option of on-line generation of new satellite configurations becomes available.

2.5.3 Antenna.

In the earlier version of the OPAL program, provision was made for specifying the following types of satellite antennas in the antenna records:

EC for earth coverage,
NC for narrow coverage,
AC for area coverage,
MBR for a 61-beam receive antenna,
MBX19 for a 19-beam transmit antenna,
MBX37 for a 37-beam transmit antenna.

We have retained the above antennas and have added the following:

SCAN for a time-shared scanning antenna,
WIDE for a wide-beamwidth (wider than EC) antenna,
ARRAY for a phased-array antenna.

Models for the three new antennas are discussed in Section 3. Here, it is sufficient to note that the SCAN and WIDE antennas are specified only by the gain values. The ARRAY antenna is used to specify the location and depth of steerable nulls in an otherwise EC antenna.

2.5.4 Transponder.

When the OPAL program user specifies an AF, D2, D3, or FL satellite, an appropriate model of the satellite with the proper number of transponders and antennas is called up. Transponder records for these satellites have not been changed. However, when the OPAL program user specifies GP, a flexible general purpose model is called up and the user must then specify the details of the antennas and transponders. The user may specify up to 25

2.5.4 -- Continued.

different transponders, each of which is connected to receive and transmit antennas from the list of nine different antenna types described in Section 2.5.3. Different types of transponders may be specified including:

linear
limiting
on-board demodulation
strong uplink (uplink effects bypassed)
frequency dehopping
on-board (or ground) PN despreading
on-board (or ground) antenna null steering.

Logical combinations (e.g., dehopping and despreading and demodulation) may also be specified. For convenience, the user is allowed to set up independent transponders if all of the parameters are identical.

2.5.5 Priority.

The priority record applies only to the D3 satellite model operating under unconstrained allocation. It is not used in the GP satellite models.

2.5.6 Jammers.

Jamming models present in the SCALE computer program were incorporated into the original OPAL computer program. However, these models were not readily accessible to the user. To correct this situation, when the OPAL user specifies GPSCS, parameters of

2.5.6 -- Continued.

postulated jammers may also be specified. Up to six jammers may be specified; parameters that are specified include jammer EIRP, location and whether it is wideband (noiselike) or narrowband (tone-like).

2.6 Control Codes.

Control codes are used to alter traffic and satellite parameters for each run. Control code records have been expanded to include information on data base masking pertaining to each run. The new format is shown in Table 1.

2.7 Use of Files.

Although details of the file organization have been modified significantly when GPSCS is specified, we retain the same basic use. Thus, accesses are developed, default values are assigned, margins are calculated and adjusted as previously.

Table 1. Format of the Control Codes File

Column	Description	
1	Blank	
2-3	Hour	Generated by program; used to identify this particular run
4-5	Minute	
6-8	Month	
9-10	Day	
11-12	Year	
13	Allocation type:	0 = unconstrained 1 = constrained
14-19	Loading margin (decibels)	
20	Timeframe C	
21	Timeframe M	
22	Timeframe L	
23	Timeframe F	
24	Priority J1	
25	Priority J2	
26	Priority J3	
27	Priority J4	
28	Priority J5	Sieves: 1 = include
29	Priority J6	0 = do not include
30	Priority J7	
31	Priority S1	
32	Priority S2	
33	Priority S3	
34	Priority S4	
35	Priority S5	
36	Scenario (seive):	0=All; 1=1; 2=2; 3=3; 4=4
37	Location preference (sieve):	0=None; 1=A; 2=E; 3=I; 4=W
38-39	Satellite code:	e.g., AF, D2, GP

Table 1. -- Continued

Column	Description	
40-41	Satellite Model: (01-99)	
42	Location:	1=A; 2=E; 3=I; 4=W
43	Line item sort	1 = print sort 0 = do not print sort
44	Submitting command sort	
45	User community sort	
46	WWMCCS sort	
47	Service type sort	
48	Receive location sort	
49	Terminal type sort	
50	Network name sort	
51	Priority sort	
52	Multiple access sort	
53	Type of operation sort	
54	Receive country sort	
55	Service availability sort	
56	Type of service sort	
57	Quality of service sort	
58-59	Mask to be applied to data base on first pass	
60-61	Mask to be applied to data base on second pass	
62-77	Similar to 57-60 for passes 3 through 10	

3. SATELLITE LINK CALCULATIONS MODIFICATIONS.

When the AFSAT, FLTSAT, DSCS-II, or DSCS-III satellite models are specified, the satellite link calculations are identical to those performed in the earlier version of the OPAL computer program. However, when GPSCS satellite models are requested by the program user, additional antenna and transponder options are available. Here, we describe those additional models.

3.1 Satellite Antenna Models.

Antenna models for the EC, NC, AC, MBR, MBX19, and MBX37 types of antennas have been completely described earlier and are unchanged from the earlier version of the OPAL computer program. We confine our remarks to the three new antenna models, SCAN, WIDE, and ARRAY.

The SCAN antenna model simulates the use of a high-gain scanning antenna. That is, the antenna is electronically (or mechanically) steered to point at specific earth terminals which time-share use of the SCAN antenna. We assume that the antenna points directly at each earth terminal and model it simply as a fixed gain with value specified by the OPAL program user. We note that the URDB does not contain data on intermittent traffic, i.e., it assumes continuous traffic requirements. Thus, the program user is repsonsible for assigning sensible traffic requirements to SCAN-type antennas, traffic which the <u>user</u> knows can time-share a receiving antenna.

Antenna model WIDE is incorporated to allow the program user to specify an antenna (such as a dipole) with a beamwidth that exceeds the arc subtended by the earth. Thus, the model is similar to an earth coverage antenna except that the gain taper off boresite is omitted. The wide antenna is modelled as having

3.1 -- Continued.

the same value of gain (specified by the program user) in the direction of all earth terminals.

Phased array antennas with steerable nulls (either on-board or ground controlled steering) are simulated with the ARRAY model. This model assumes that an earth coverage pattern (including off-axis taper) is used but that up to N steerable nulls, where N are the number of jammers, are superimposed on the nominally EC pattern. Each null has the same null depth and beamwidth, specified by the OPAL program user. The pointing latitude/longitude of each null is specified by referring to the jammers to be nulled. The program assumes pointing at the latitude/longitude of the jammer. The model then introduces a negative gain pattern using the same modified ($\sin^2 x/x^2$) subroutine used for NC, AC, and EC coverage.

3.2 Satellite Transponder Models.

A large number of different transponder features are available to the OPAL program user. The user selects the desired transponder features along with the transmit and receive antennas connected to that transponder; another transponder with its antenna types can then be specified. Up to 25 independent transponders may be selected for a GPSCS satellite.

Linear transponders include uplink noise and power sharing effects, along with frequency translation. When limiting is specified, signal suppression and intermodulation models (the same as described earlier) are added. On-board demodulation ignores uplink effects. When the received power does not exceed a user-specified threshold, the same calculations are performed but an uplink limitation warning is printed. The warning is bypassed when a strong uplink

3.2 -- Continued.

is specified by the program user. These features were present in the DSCS-II, DSCS-III, AFSAT, and FLTSAT models used in the earlier version of the OPAL program and were retained.

When on-board frequency dehopping is specified, the frequency-hopping processing gain (ratio of hopped bandwidth to instantaneous bandwidth) specified by the OPAL program user reduces the uplink received jamming power by the value of that processing gain. This model is accurate when the jammer spreads the power over the entire hopped bandwidth. When a jammer spreads the power over a different bandwidth, the model becomes inaccurate; however, no provision for altering it is included.

Despreading a pseudonoise (PN) sequence introduces a PN processing gain against the jammer. Processing gain is realized on either the uplink or the downlink as specified by the OPAL program user. Specifying despreading on the ground means that full jammer power is applied to the power sharing, signal suppression, and intermodulation routines. Jamming power (uplink or downlink) is reduced by the PN processing gain when the jammer is narrowband. If the jammer is already wideband, little additional spreading occurs and a nominal 2 dB decrease in effective jamming power is used in place of the PN processing gain. Since on-board despreading implies a large amount of satellite hardware, the number of accesses in each transponder is printed out to aid the OPAL program user in assessing the hardware implications.

When an ARRAY antenna model is used, the calculated null depth is applied against jammers and signals on either the uplink or downlink depending upon whether the nulls are synthesized on-board the spacecraft or on the ground (by transponding all feeds).

3.2 -- Continued.

The OPAL computer program assumes that sufficient channels are available for each of the feeds and that the calculations are identifical for each feed.

The OPAL program user can cascade transponder features. For example, antenna nulling, frequency dehopping, PN despreading and demodulation can all be specified and the program makes all of the appropriate adjustments.

4. SATELLITE LOADING MODIFICATIONS.

In the earlier OPAL computer program, once link margins were established, transponder power was raised or lowered to meet the desired margin and loading was reported as a percentage of the nominal power. When link performance is dominated by uplink jamming, this last step is not appropriate. Thus, the modified OPAL computer program determines if the signal-to-jamming ratio exceeds the required SNR by at least the desired margin and omits the satellite power adjustment if the test fails. The program will print out a warning, including the worst-case value of signal-to-jamming ratio whenever the power adjustment is bypassed.